Electronic autopilot type C-1

By Gerard E. Nistál

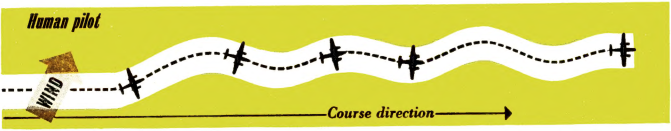
IN April, 1941, eight months before the Pearl Harbor debacle, Col. Douglas M. Kilpatrick, then Chief of the Bombardment Section of the AAF Materiel Command, was a spectator at a demonstration of a new electronic control system by a company which had never engaged in either research or production for the aviation industry. Previous to 1940 it had been engaged in manufacturing in truments and control systems for air conditioning, heating and refining. As war grew more imminent, periscopes, periscopic and telescopic gunsights and controls for wartime production lines supplanted its peacetime products. The formation of an Aeronautical Division introduced a new field which was explored to the extent of the development of what is known as a turbo-regulator control. This is a sensitive unit that automatically regulates the turbosuperchargers in multi-engined aircraft giving maximum engine horsepower output at all times regardless of altitude changes involving pressure or temperature differences.

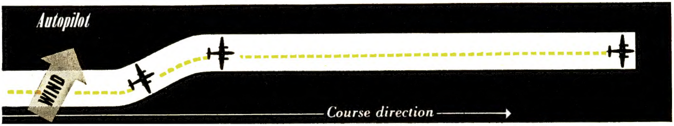
Immediately after this took place, Col. Kilpatrick initiated a broad-scale development program with the intent of adapting electronic control equipment to AAF requirements. Five months later, in September, 1941, the first electronically controlled automatic pilot was accepted by the AAF Materiel Command, and in another five months, planes equipped with these auto- pilots were coming off the production lines. In April, 1942 — one year after the initial conception of the idea, these planes were in combat over Africa and the Pacific. A few months later, Col, Kilpatrick was accidentally killed in line of duty, but before his untimely death he was granted the satisfaction that his trust was well- placed, that the equipment was proving its worth in combat.

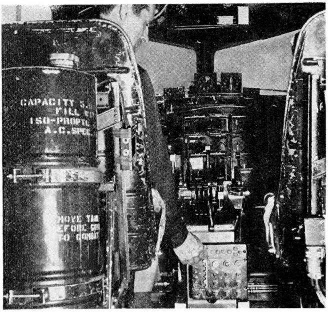
The C-1 Autopilot was a military secret until it had been definitely established that aircraft so equipped had been shot down in enemy territory and its existence thus made known to the Axis. Ten months ago, the fact that it existed was released to the public, but it was not until April of this year at the Northwest Aviation Exposition at Minneapolis that the Minneapolis-Honeywell Regulator Company was able to publicize its innovation in aircraft control. Installed in a Link trainer, the equipment was demonstrated to the public, who had an opportunity to "fly" and check the instantaneous responses of the electronic mechanism.

Equipment

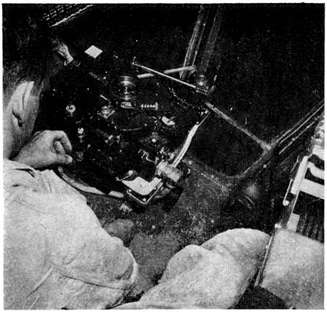
The Type C-I Autopilot consists of nine integral units connected in various ways according to the particular type aircraft. Three servo units drive the movable control surfaces (rudder, elevators and ailerons) by means of cables clamped to the regular control cables. The direction of movement is controlled by electrically operated clutches between an electric motor and a cable drum in each unit. Since the servos are installed near the surfaces that they control, the cables are short and are therefore less affected by temperature changes and less likely to be damaged by gunfire than the manual control cables. The directional stabiLizer, located in the nose of the plane, contains a horizontal gyro which controls the attitude of the ship in the vertical or yaw axis. Attached to its side is a directional panel applying electrical signals to steer the airplane. This panel is connected to the stabilizer gyro through the autopilot clutch. When the clutch is engaged, the stabilizer steers the plane; when it is disengaged the bombardier can steer the plane manually. The pilot can engage and use the autopilot in navigational flights without assistance from the







Control panel mounted in the pilots' compartment of a B-17 series Fortress. Max Conrad, an M-H test pilot, is charged with responsibility of checking instruments' flight characteristics.



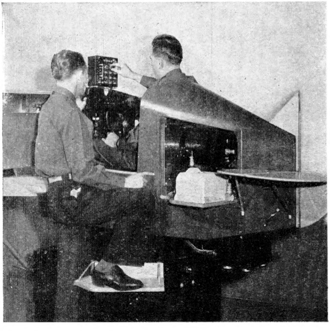
View of the directional stabilizer of a Type C-1 Autopilot, mounted in the bombardier's compartment of a Consolidated B-24. Unit contains horizontal gyro for directional reference.

bombardier, provided the clutch is engaged. This will be explained in a following section.

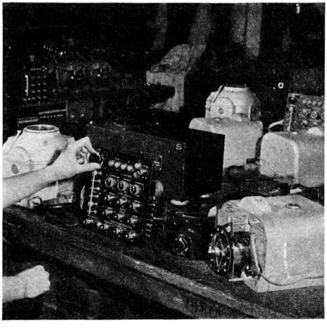
The *vertical flight gyro* controls the attitude of the plane in the pitch and roll, or horizontal and longitudinal axes. When the autopilot is engaged, this instrument measures electrically any pitch or roll deviation of the plane and produces signals which direct the servo units to correct the deviation. The *amplifier* controls the operation of the servo units, causing them to move the control surfaces in response to corrective signals from the vertical and horizontal gyros. The *rotary inverter* converts dc from the airplane's batteries into ac required by the amplifier and control units, while the *junction* or *J box* provides terminals for interconnecting the various wires of the circuit. The *control panel* is used for engaging the autopilot and adjusting its operation to compensate for changes in flight conditions. After the knobs are set, no further adjustments are necessary unless flight conditions change. A turn control is provided which permits the pilot to make coordinated control or bombardier's turns without disengaging the autopilot.

The outstanding differences between the C-1 Autopilot and others in use at present are that it is completely electronically controlled, instead of being operated hydraulically or by air pressure, and that no flight instruments are duplicated, such as the directional gyro, the artificial or gyro horizon indicator, and turn-

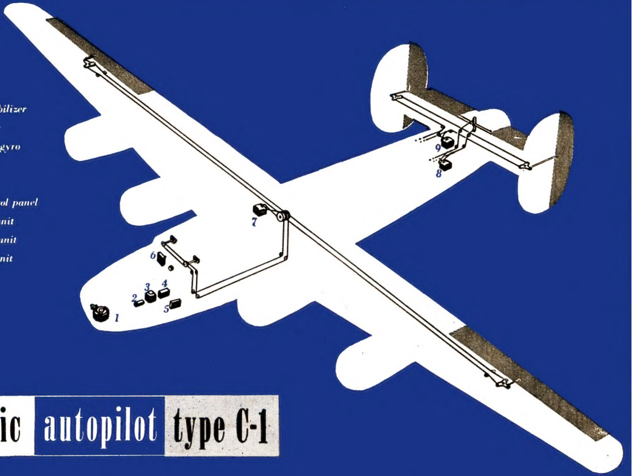
Students at company school use electronic autopilot installed on Link trainer. Note servo motor in front of elevator. M-H trains pilots, bombardiers, maintenance men in use of system.



Each unit of every system is thoroughly tested before installation. In this view, from left to right, can be seen vertical flight gyro, junction box, amplifier, control panel, three servo units.

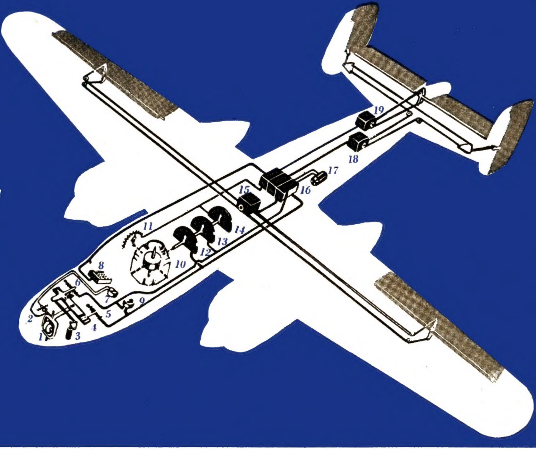


1 *Directional stabilizer*
2 *Rotary inverter*
3 *Vertical flight gyro*
4 *Amplifier*
5 *Junction box*
6 *Autopilot control panel*
7 *Aileron servo unit*
8 *Elevator servo unit*
9 *Rudder servo unit*



Electronic autopilot type C-1

1 *Directional stabilizer*
2 *P.D.I. pot*
3 *Dash pot*
4 *Directional panel*
5 *Banking pot*
6 *Rudder pick-up pot*
7 *P.D.I.*
8 *Autopilot control panel*
9 *Turn control*
10 *Vertical flight gyro*
11 *Elevator pick-up pot*
12 *Aileron pick-up pot*
13 *Skid pot*
14 *Up-elevator pot*
15 *Aileron servo*
16 *Amplifier*
17 *Rotary inverter*
18 *Rudder servo*
19 *Elevator servo*

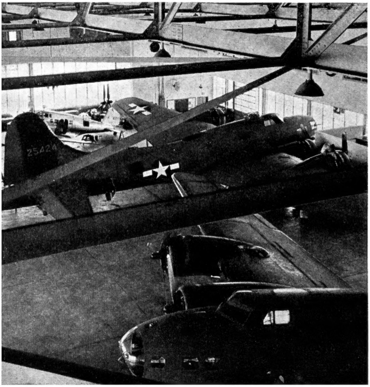


and-bank indicator. The electronic system makes use of the above standard instruments already installed in the instrument panel plus the standard sensitive altimeter and a PDI (Pilot's Directional Indicator).

Principles of Operation

There is also the difference that in all other types of automatic pilots the bombardier directs the pilot via the intercom as far as course, altitude, and speed are concerned while on a bombing run. In the case of the electronic unit, the directional stabilizer is mounted in the bombardier's compartment in direct conjunction with the Norden bombsight, and he, himself, controls the movements of the plane by manipulating two clutch controls. His field of control is limited to 36 degrees. When the bombsight clutch is engaged during the bomb run, the stabilizer holds the sight on a fixed heading. Thus, during actual bombardment runs, the bombardier can exclusively control the plane's flight. After the bombing run has been completed, the bombardier who, for a few seconds over the target has been piloting the big ship, returns full control to the pilot. Prior to the bombardier's selecting the target heading and making the run, the pilot checks his bombing airspeed and altitude, turns the master and PDI switches on, but leaves all other engaging switches in the off position. After the bomb bay doors are open, he sets trim tabs for straight and level flight, centers the PDI and engages the autopilot. Adjustments for accurate flight control and coordinate bombardier's turns are then made through four sets of manual control panel knobs: centering, sensitivity, ratio, and turn compensation, one knob for each control surface, making twelve knobs in all. The latter knobs are used for bank, skid and altitude loss compensations, while one master knob is used to control all turns. In addition, the dashpot must be adjusted and locked so that

Fortresses assigned to Minneapolis-Honeywell as test ships parked in company hangar; this is the largest aero laboratory in the Northwest, containing machine shops, electronic labs, complete overhaul and modification equipment.



the autopilot will hold PDI. Its purpose is to produce an increased initial reaction of the rudder, simulating the "rudder kick" which a human pilot uses in correcting a sudden deviation in the turn axis. If set too loose, PDI will waver with irregular movements; if it is set too tight, the ship will "hunt" in the turn axis, as indicated by a periodic oscillation of the PDI.

Operational Hints

Unless it is known that the control panel is already in correct adjustment, it is well to turn all knobs to their mid-positions before engaging, with the exception of the control transfer which should be left at PILOT, and the tell-tale light shutter should be left ON. The master switch starts all electric motors except the torque motor in the stabilizer, and should be turned on immediately after take-off so the units will be kept warm as cooler altitudes are reached. The autopilot will not control the airplane until the aileron, rudder and elevator switches are turned on. A warmup period is required after the master switch is turned on to allow the gyros in the stabilizer and vertical flight gyro to come up to speed. The servo-PDI switch is then turned on in order to connect the PDI dial on the instrument panel with the PDI dial on the directional stabilizer in the bombardier's compartment. This switch also starts the torque motor which opposes any force tending to precess the stabilizer gyro. The ship is then manually trimmed with reference to the artificial horizon, bank-and-turn indicator, sensitive altimeter and rate-of-climb indicator. With the plane flying straight and level, the autopilot clutch is disengaged and the PDI is centered by moving the autopilot clutch arm to the center of its travel. After it is exactly centered, the directional arm lock is pressed down to hold the clutch arm in position while the pilot continues his engaging procedure.

Control panel lights should be extinguished by adjusting aileron and rudder centering knobs, and corresponding switches should be turned on, after the autopilot clutch is reengaged and the directional arm lock released.

Both centering knobs should be readjusted to level wings and to center both PDI and gyro-horizon; the elevator centering knob can also be adjusted to check with the altimeter and rate-of-climb indicator. The sensitivity knobs are used to regulate the amount of deviation the autopilot will allow before it applies correction. High sensitivity provides maximum flight stability.

The ratio knobs regulate the amount of control movement applied to correct a given deviation. Correct ratio produces quick recovery without overshooting or sluggish control response.

The dashpot is a small oil-filled cylinder in which movements of a plunger are damped by the oil, and assures that the autopilot will hold PDI with correct adjustment.

There is really nothing new in automatic pilots, per se. They have been used for more than a decade in commercial air transport and almost as long in combat aircraft.

However, this Type C-1 Autopilot was designed primarily for precision bombing and is used to hold bombers on the exact course determined by the bombardier, who, during the course of a bombing run, actually has complete control over the plane's movements. With a precision unattainable by human

means, a stable platform is thus provided which is essential if bombs are to be dropped accurately from high altitudes. During the few seconds of its bomb run, the airplane must not deviate from its set course by a single degree. At 25,000 feet, according to precision bombing experts, an error of one mil means that the bomb will miss the target by 360 feet. Yet a bomber weighing 25,000 pounds is free to move up or down, sideways, or tip from right to left. It may be said that the C-1 Autopilot is capable of making over 300 flight corrections a minute or more than five every second. Gyroscopes are used, as m other types, but the movements of the plane about spinning gyro rotors — so delicate that they must be oiled with only one drop from a hypodermic needle — are picked up electronically. These movements are amplified into a force strong enough to actuate the control surface motors which, in turn, move the control surfaces and bring the plane back to its set course. The whole process is practically instantaneous.

In addition, the autopilot makes possible the use of remote control stations so that the airplane may be flown from one or more positions. In one instance, a Boeing *Fortress* flew home after being almost cut in two in a mid-air collision with a Nazi Messerschmitt. All manual control cables connected to elevators and rudder were severed, but the ship was flown safely back on the autopilot because the control surface motors of the system were located far in the tail and were not damaged in the crash.

Training Program

New in principle and operation, this unique system was unfamiliar to both pilots and crews alike. First step to educate these men was the establishment of a school in Minneapolis operated by the manufacturer. Simultaneously, a Field Service Division was organized and its men sent to al! major air bases and eventually to every fighting front on the globe. Final step was the production of eleven training films for the AAF by Walt Disney. These films start out with a simplified explanation of electricity and basic electronics. From this point, they become more specific and are applied directly to the autopilot, ending with a confidential instruction film showing full bombing procedures. These training films have been distributed to meet medium bombardment squadrons whose planes are equipped with the C-1 installation, aircraft and radio mechanic training centers, pilot and bombardier schools, and are an integral part of the courses given by the company school and field service representatives.

The sensitivity of this electronic system is a tribute to the engineering skill of American industry. This is true to such an extent that it is interesting to note that the plant is located at 45 degrees north latitude so the gyroscope "tilt table" is tilted at the same degree, thus making possible exact checks on the gyro's ability to maintain an upright position at all times in flight.

AAF bombardiers assigned to multi-engined aircraft, interviewed by an *Air Tech* staff correspondent, have been unanimous in praising the Minneapolis-Honeywell autopilot. One, in particular, at an air power show in New York, mentioned that if it weren't for his autopilot, his name would have been mud instead of Mudt!

This article was originally published in the August, 1944, issue of *Air Tech* magazine, vol 5, no 2, pp 31-34, 68.
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